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Effect of Biochar from Different Origin on Physio-Chemical Properties of Soil and Yield of Garden Pea (*Pisum sativum* L.) at Paklihawa, Rupandehi, Nepal

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Abstract A field experiment was conducted at the Horticulture farm of Paklihawa Campus, Institute of Agriculture and Animal Science, Rupandehi district to observe the effect of biochar from different origin on physio-chemical properties of soil and yield of garden pea (*Pisum sativum* L.) and evaluate them. The experiment was laid out in a Randomized Complete Block Design with four replications. A set up constituted of various treatments viz. rice husk biochar, poultry manure biochar, sheep manure biochar, farm yard manure biochar and wood biochar along with the control group. Results showed that number of pod/plant, number of seed/pod and biomass (ton/ha) were significantly affected by application of biochar of different origin. Application of rice husk biochar had higher effect on number of pod/plant, no of seed/pod, biomass (ton/ha) and green pod yield (ton/ha). Biochar of Poultry manure and of sheep manure had almost similar effect on soil nitrogen as of other types of biochar, while higher effect on soil phosphorus and potassium as compared to other biochar. Biochar of sheep manure had higher organic matter content and carbon percentage in soil than all other application of biochar. Application of all types of biochar showed highly significant results on bulk density and particle density. It was found that biochar of rice husk had greater particle density 2.61 g/cc and all the application had decreased bulk density except that of biochar prepared from wood. Thus, the soil where biochar was applied was found to be of better quality than that of the controlled one where no biochar was used. These results suggest that biochar could be one of the best options in poor quality soil and where burning practices are mostly adopted for cleaning the field.

Keywords: *biochar, carbon percentage, garden pea, physiochemical properties, soil amendment*

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1. Introduction

The increasing problem of decreasing soil fertility in many developing nation such as, Nepal has brought forward the importance of technologies that are locally available, economically feasible and environment friendly. Generally, the stubble left after harvesting rice and wheat using combine harvester are usually, burnt on the field. This is a common practice of Nepalese farmers, to clean the field for the next cultivation. This practice is consider as unscientific because heavy nitrogen and moisture are lost, the soil micro flora & fauna are disturbed as well as the potassium content of field increases to significantly high level. Likewise increases the chances of fire hazard.

Therefore, application of biochar seems to be the reasonable solution to the nation like ours. While talking about "Biochar", it is a relatively new term, yet it is not a new substance. Biochar is also called as bio-char, charcoal or biomass derived as black carbon, and recently Agri-coal/Agri-Char etc. based on the purpose of use [4]. According to Ogawa (undated), biochar is described by Miyazaki as 'fire manure' in an ancient Japanese text on agriculture dating from 1697. Soils throughout the world contain biochar deposited through natural events, such as forest and grassland fires [34]. Biochar is commonly defined as charred organic matter, produced with the intent to deliberately apply to soils to sequester carbon and improve soil properties [20]. Biochar is the porous carbonaceous solid produced by thermochemical conversion of organic materials in an oxygen depleted atmosphere which has physiochemical properties suitable for the safe and long-term storage of carbon in the environment and, potentially, soil improvement [10].

Biochar is a carbon rich product that is produced by pyrolysis (heating in incomplete or partial absence of oxygen) of biomass at relatively low temperature (<700°C) [10,26]. The efficiency and effectiveness of the process of its creation and use can vary and the specific biomass sources used can affect the characterization and usability of the biochar [10,11]. Some of the attributes that might be expected from biochar can go beyond just physical characteristics to issues of whether the feedstock used in its creation was from a renewable feedstock, whether its production reduced greenhouse gas emissions and whether the biochar can improve soil quality in a reliable way (International Biochar Initiative, 2009). However, biochar is different from others because of the intention to incorporate in soil for agricultural and environmental benefits. Biochar is recently a huge interest for everyone mostly because of its two attributes. First, most of the carbon in biochar is relatively stable in the soil. This property makes biochar one of the potential tools to mitigate climate change through carbon sequestration in agriculture soil. Second, biochar has shown dramatic effects on plant production. Until 2011, 50% of researches were positive, 30% were negative, and 20% were indifferent regarding application of biochar as a soil amendment. However, there are also results with no significant effects on plant production or reduced performance when biochar is applied on growth and yield [17]. In the case of garden pea, *Pisum sativum* L., i.e. a leguminous plant, biochar has significant effect. The application of biochar helps to increase the growth of plants and the no. of pods per fruit and its test weight. It is believed that legumes become three times as abundant and individual legume plants increase four times in biomass in plots that received biochar [43].

Compared to other soil amendments, the high surface area and porosity of biochar enables it to adsorb or retain nutrients and water and also provides a habitat for beneficial microorganisms to flourish [16,21,41]. Laboratory studies using the latest technology estimate that biochar has a mean residence time in soils approximately 1300–4000 years [7,22]. It is estimated that use of this method to “tie up” carbon has the potential to reduce current global carbon emissions by as much as 10 percent [42]. While a greater proportion of micro-pores may yield a higher surface area, and thus greater nutrient retention capability, many soil microorganisms are too large to utilize such small spaces and benefit from some amount of larger pore sizes [41]. For soils that require liming, there is growing evidence that biochar may provide similar benefits of improving soil pH balance [42].

Cropping system of most developing nation such as, Nepal is mostly urea based. Their heavy use has led to other harmful effects like poor soil structure, nitrate in the ground water, adulteration of food materials, eutrophication, etc. High agricultural inputs are doubtful to be sustainable for long run unless the inputs are judged correctly in terms of both their quality and quantity. Unavailability of irrigation facility and dependence on monsoon is the bitter truth of our country. A few studies of biochar application on crops suggest that biochar may enhance soil moisture retention. This attribute of biochar may lessen the effects of drought on crop productivity in drought-prone areas [24]. Biochar is best option due to its ability to attract and retain water owing to its porous structure and high surface area.

Acid rain, deforestation, smog due to automobiles and discharge of industrial pollution has led to degradation of soil nutrient and structure. Not only this, the ozone layer is also depleting and environmental hazards are accelerating. Research has revealed that the production of nitrous oxide and methane, two extremely potent greenhouse gases, was reduced under certain conditions when biochar had been applied to soil. The process of creating biochar could sequester billions of tons of carbon from the atmosphere every year (somewhere approximately 5-30% of global emissions) while simultaneously producing clean renewable energy to replace fossil fuels [42]. Biochar is an inexpensive, simple, local-based option for soil amendment.

Biochar can lead to faster decomposition rates of native carbon stocks in soils. Poor biochar production practices could actually lead to greater greenhouse gas emissions and detrimental air quality. Considering all these problems and factors, field experiment was conducted on biochar from different origin with the following objectives:

- To identify the effects of different origin biochar on soil structure.
- To identify the effect of biochar from different origin on soil nutrient status.
- To determine the effects of different origin biochar on different biological parameters of Garden pea such as plant height, pod length, pod weight, number of grains per pod, dry weight of plant etc. and productivity response.

2. Materials and Methods

2.1. Description of the Experimental Site

The field experiment was conducted at the Horticulture farm of Paklihawa Campus, Institute of Agriculture and Animal Science (IAAS) of Rupandehi district during November 2014 to May 2015. This site is located in inner Terai region of western development region of Nepal. The experiment was conducted on the field where vegetable crops like tomato, spinach, broad leaf mustard etc. were previously cultivated. The physio-chemical properties of the soil of experimental site before the commencement of experiment is shown in Table 1.

Table 1. Physio-chemical properties of the soil of Paklihawa, Rupandehi, Nepal, 2014/2015

Soil Parameters	Values
Total N (%)	0.04
Available P_2O_5 (kg/ha)	39.47
Exchangeable K_2O (kg/ha)	227.8
Organic matter (%)	0.78
Organic Carbon	0.45
pH	7.5
Bulk density (g/cc)	1.79
Particle density (g/cc)	2.54

Monthly average for maximum-minimum temperature and total rainfall recorded during the experiment is shown in Figure 1.

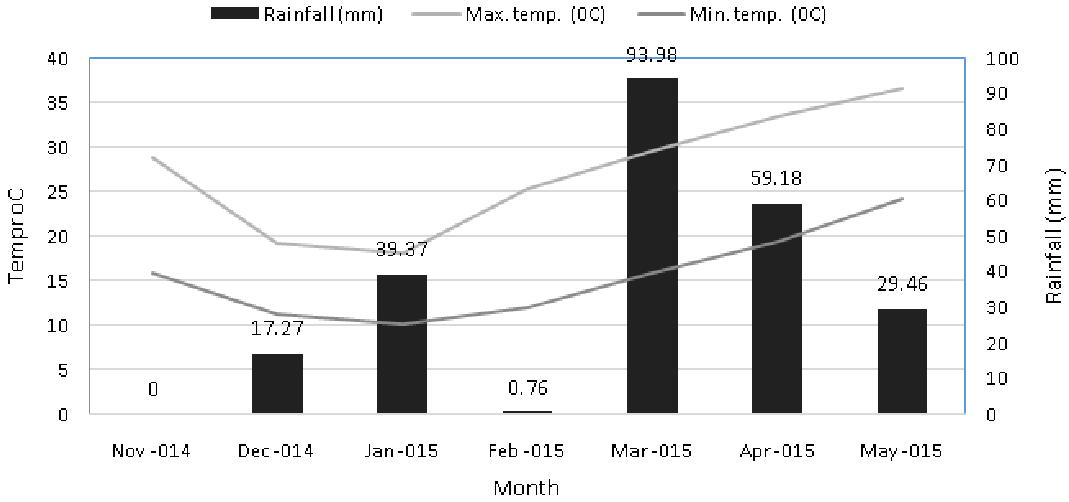

Figure 1. Climate of experimental site showing temperature & rainfall pattern during the cropping period at Paklihawa, Rupandehi, Nepal, 2014/15

(Source: Agro meteorological data recorder, Bhairahawa Airport of Rupandehi district, Nepal)

2.2. Experimental Detail

The experiment was conducted in Randomized Complete Block Design (RCBD) with four replications and six treatments. The experiment field was divided into in 24 plots each of size 1.5m X 1.5m. The spacing of 1m between each replication block and 50 cm between each treatment plot was provided. The experiment included six level of treatment, out of which five was biochar prepared from rice husk, poultry manure, sheep manure, farmyard manure and wood and one was a control. The samples was dried in shade to remove excess moisture. The biomass was later combusted excluding oxygen in locally prepared stainless steel drum, which was especially designed for preparing biochar.

Table 2. Treatment details used in experimentation

Treatment Number	Treatment
T_1	Control
T_2	Rice Husk Biochar
T_3	Poultry Manure Biochar
T_4	Sheep Manure Biochar
T_5	Farm Yard Manure Biochar
T_6	Wood Biochar

Application rate of Biochar was 10 ton ha^{-1}. The application of the biochar was done 15 days prior to sowing of seed. Priming of Seed 24 hour before sowing was done. Plant to plant spacing is maintained 7 cm and row to row spacing is maintained 45 cm. There were 3 row in each plots and 20 plants in each row and total of 60 plants per plot.

2.3. Cultivation Practice Adopted

Two ploughing followed by harrowing was done manually to break down the clods. Water channels were made around the field and the plots were raised few centimeter than the normal level of the field. Garden pea (*Pisum sativum L.*) seeds was brought from Siddhartha Agrovet of Bhairahawa Market. Amulya-10 was the variety used for the experiment. Two seeds per hill was sown with three rows and twenty hills per row in a single plot of 2.25 m^2 area. No any chemical fertilizer was applied in the experimental field. Irrigation was done at regular interval in the field. For the control of weeds, manual weeding and hoeing was done at a regular interval in the field.

2.4. Observations

2.4.1. Recording of Soil pH, Nitrogen, Phosphorous, Potassium and Organic Matter Content

Soil samples were collected in Z-shape from five spots of entire experiment field at a depth of 20 cm before the application of biochar. A composite sample was made from the above collected soil sample. Similarly, final soil sample was collected from each plots, total 24 samples were taken after harvesting. It was then shade-dried, ground, sieved through 2 mm sieve and then subjected to determine their major nutrient status of the experimental site. Their nutrient status was determined using following analysis method:

Table 3. Method of laboratory analysis

Parameters	Analysis methods
Soil pH	Beckman Glass Electrode pH meter (Wright, 1939)
Soil organic matter	Walkley and Black (1934)
Soil total nitrogen	Kjeldahl distillation (Bremner and Mulvaney, 1982)
Soil available phosphorus	Olsen's bicarbonate (Olsen *et al*.., 1954)
Soil available Potassium	Ammonium acetate (Black, 1965)
Soil bulk density	Undisturbed core sampling method
Soil particle density	Using pycnometer

2.4.2. Phenological Observation of Garden pea

Ten sample plants from each plot were selected randomly to determine various phenological character such as plant height, yield attributing character and yield. The height was measured from the point near to soil surface to the longest portion of the plant tip. The following parameters were taken under consideration: Number of pods/ plant, No of seeds/ pod and Green pod yield (ton/ha).

2.5. Statistical Analysis

All the recorded data was compiled and analyzed through MSTAT-C package. Mean was separated by Least Significant Difference test (LSD) and Duncan's Multiple Range Test (DMRT). Pearson's correlation coefficient and simple linear regression was run between selected parameters wherever necessary using SPSS ver. 20.

3. Result and Discussion

This section includes the treatment effects emanated from the field experiment. The treatment effects are presented in the table and are also illustrated with suitable figures wherever necessary. Beside, an attempt has been made to evaluate the result to obtain and to offer explanations with available evidences wherever possible for the observed variation in the mention parameters.

3.1. Effect of Biochar on Pea Height

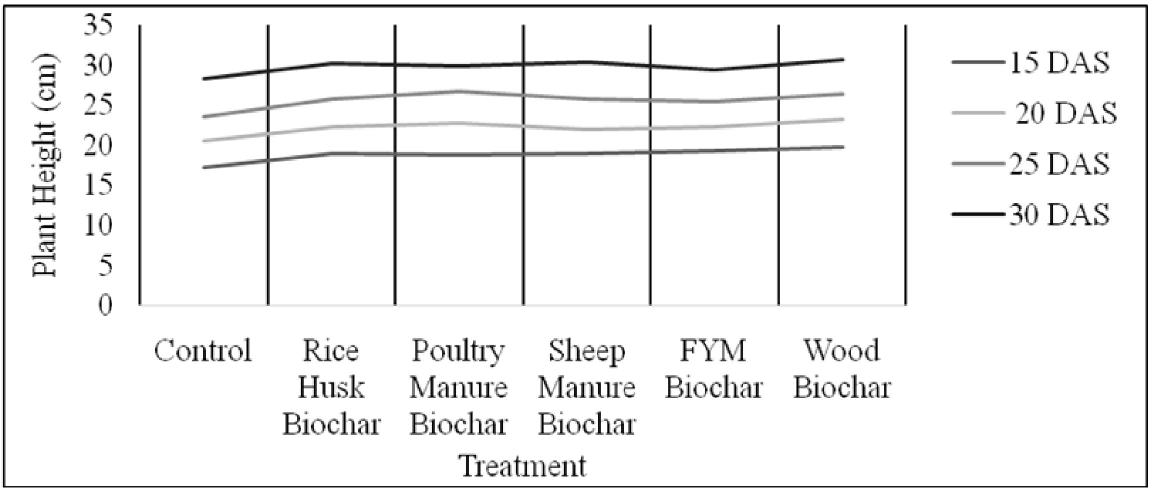

Figure 2. Effect of application of different origin biochar on plant height of pea at Paklihawa, Rupandehi, Nepal, 2014/15

Table 4. Effect of application of different origin biochar on plant height of pea at Paklihawa, Rupandehi, Nepal, 2014/15

Treatment	Plant height 15 DAS (cm)	Plant height 20 DAS (cm)	Plant height 25 DAS (cm)	Plant height 30 DAS (cm)
Control	17.250[a]	20.500[a]	23.500[a]	28.250[a]
Rice husk biochar	19.000[a]	22.250[a]	25.750[a]	30.250[a]
Poultry manure biochar	18.750[a]	22.750[a]	26.750[a]	30.000[a]
Sheep manure biochar	19.000[a]	22.000[a]	25.750[a]	30.500[a]
FYM biochar	19.250[a]	22.250[a]	25.500[a]	29.500[a]
Wood biochar	19.750[a]	23.250[a]	26.500[a]	30.750[a]
SEm	1.085	1.072	1.012	0.956
LSD (0.05)	3.271	3.233	3.052	2.881
CV %	11.520	9.680	7.940	6.400
Grand mean	18.833	22.167	25.500	29.875

Note: Treatment means followed by common letter(s) are significantly different from each other based on DMRT at 5% level of significance.

Plant height of pea was non-significant in all parameters such as height at 15, 20, 25 and 30 DAS (Table 4). There is no substantial difference for application of different origin biochar on plant height. Conversely, the plant height is small in plot with no biochar application in contrast to plot with biochar application (Figure 2). Generally, there is a positive relationship between plant growth and biochar in the soil.

3.2. Effect of Biochar on Yield Attributing Character of Pea

Number of pod/plant, number of seed/pod and biomass (ton/ha) were highly significantly affected by application of biochar of different origin (Table 5). However, green pod/plant had no significant effect for biochar application.

Biochar application for each yield parameters are represented under Table 5.

Table 5. Effect of application of different origin biochar on various yield attributing character of pea at Paklihawa, Rupandehi, Nepal, 2014/15

Treatment	No. of pod/plant	No. of seed/pod	Biomass (ton/ha)	Green pod yield (ton/ha)
Control	13.000[c]	5.500[c]	5.542[c]	5.480[ab]
Rice husk biochar	18.750[a]	8.500[a]	9.388[a]	8.326[a]
Poultry manure biochar	16.500[b]	6.750[b]	7.084[b]	7.401[a]
Sheep manure biochar	15.750[b]	6.500[b]	5.816[c]	5.998[ab]
FYM biochar	16.500[b]	5.250[cd]	5.225[c]	5.743[ab]
Wood biochar	12.250[c]	4.500[d]	4.051[d]	3.637[b]
SEm	0.3446	0.2933	0.2855	1.015
LSD (0.05)	1.039**	0.884**	0.861 **	3.058
CV %	4.460	9.520	9.230	33.280
Grand mean	15.458	6.167	6.184	6.098

Note: Treatment means followed by common letter(s) are significantly different from each other based on DMRT at 5% level of significance.

3.2.1. Effect of Biochar Application on Number of Pod/Plant

No. of pod/ plant is highly significant to the treatment. Rice husk biochar application has higher effect on number of pod/plant. While poultry manure biochar, sheep manure biochar and FYM biochar have similar effect on number of pod per plant. Wood biochar and control treatment have similar and less effect on number of pod/plant.

3.2.2. Effect of Biochar Application on Number of Seed/Pod

Rice husk biochar has higher effect on number of seed/pod. Poultry manure and sheep manure biochar have similar effect. However, wood biochar has least effect on this factor. FYM biochar had similar effect as of wood biochar and control condition.

3.2.3. Effect of Biochar Application on Biomass (ton/ha)

Rice husk biochar has higher effect on biomass yield. Whereas poultry manure biochar has second best option for rice husk. Sheep manure biochar, FYM biochar and control condition have nearly same effect, and hence can replaced for one another. Wood biochar has its less effect than all other biochar application.

3.2.4. Effect of Biochar Application on Green Pod Yield (ton/ha)

Rice husk biochar and poultry manure biochar have significantly same and higher effect. Wood biochar has least effect, however comparing with control condition, sheep manure biochar and FYM biochar have similar effect.

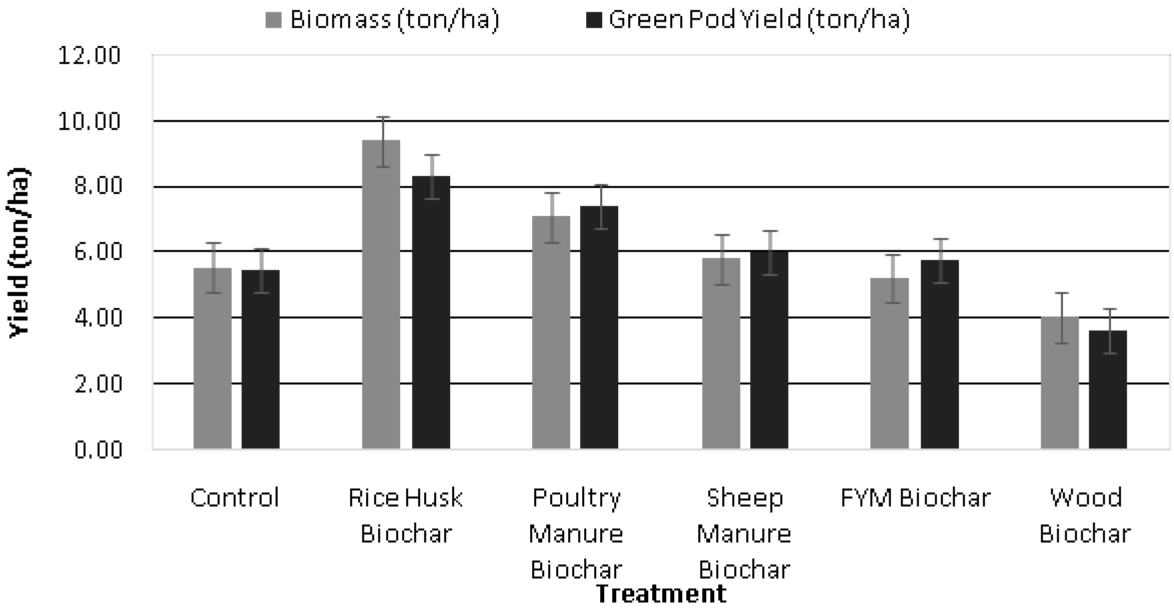

Figure 3. Effect of application of different origin biochar on biomass and green pod yield of pea at Paklihawa, Rupandehi, Nepal, 2014/15

From Figure 3 i.e. effect of application of biochar of different origin, it has been found that rice husk biochar is best application for the yield of the pea. In addition, wood biochar has least effect on these yield-attributing characters among all other application. Nevertheless, various author have reported wood biochar are also of superior quality; however rice husk have showed best performance in first year of cropping. Milla *et al.*, in 2013 have proposed the decomposition of wood biochar was faster than rice husk biochar under a lower dosage amount (< 1.5 kg/m^3), but this trend was inversed with a higher dosage (> 3.0 kg/m^3). Similar studies showed that rice husk biochar had better holding capacity than wood-based biochar. Due to the differences in their particle size, rice husk biochar was able to integrate better into soil making the distribution uniform. Carter in 2013 have reported the biochar treatments were found to increase the final biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatments.

3.3. Effect of Biochar Application on Chemical Properties of Soil

Application of biochar of different origin have highly significant results on soil nitrogen percentage and pH of soil. Application have no significant result on soil potassium. Nevertheless, potassium content of soil increased by the application of biochar than in control condition. Different origin biochar application have found to have some amendment on soil properties Table No 6.

3.3.1. Effect of Biochar Application on Soil Nitrogen

Poultry manure biochar, sheep manure biochar have almost similar and higher effect on soil N, and low N percentage were recorded in the FYM biochar and rice husk biochar. According to the experiment conducted by the Chan *et al.*, in 2008, biochar have lower nitrogen content. Biochar addition to the hard setting soil resulted in significant in increasing total nitrogen but different changes in soil chemical and physical properties, including increases in C, N, pH, and available P, but reduction in soil strength.

3.3.2. Effect of Biochar Application on Soil Phosphorus

The results from biochar application of different origin on phosphorus has least significant difference in having intermediate results, but it has been found that biochar application has slow increasing effect on soil phosphorus in all cases of application than in control condition. Among all application, poultry manure biochar has higher phosphorus contribution on soil (82.527ton/ha) and lowest (38.122) in control condition (Table 6). According study conducted by Agusalim Masulili in 2010, biochar increases the available P in soil as biochar increases the soil pH, which makes immobile Phosphorus available.

3.3.3. Effect of Biochar Application on Soil Potassium

The results found that there were no significant different between the applications of biochar of different origin. However all application of biochar in soil have increasing effect on soil potassium. Poultry manure biochar and sheep manure biochar have greatly increased the potassium content of the soil as compared to other biochar. Agusalim Masulili also draws similar conclusion in 2010 in acid sulfate soils and rice growth in West Kalimantan, Indonesia. Significant increase in exchangeable Potassium was recorded by the application of biochar.

Table 6. Effect of application of different origin biochar on various chemical properties of soil at Paklihawa, Rupandehi, Nepal, 2014/15.

Treatment	Nitrogen %	Phosphorous (P_2O_5) (kg/ha)	Potassium(K_2O) kg/ha	pH
Control	0.077^b	38.122^c	207.800^b	7.800^b
Rice Husk Biochar	0.095^{ab}	47.540^{bc}	314.750^a	8.300^a
Poultry Manure Biochar	0.105^a	82.527^a	270.618^{ab}	8.400^a
Sheep Manure Biochar	0.113^a	65.505^{ab}	305.618^a	8.375^a
FYM Biochar	0.080^b	48.887^{bc}	301.500^a	8.250^a
Wood Biochar	0.098^{ab}	50.677^{bc}	314.900^a	8.400^a
SEm	0.006	8.217	29.400	0.063
LSD (0.05)	0.019**	24.770*	88.630	0.191**
CV %	13.500	29.590	20.580	1.510
Grand Mean	0.095	55.543	285.771	8.354

** represents the highly significant results at 1% level of significance and * represents significance results at 5% level of significance. (Note: Treatment means followed by common letter (s) are significantly different from each other based on DMRT at 5% level of significance.).

3.3.4. Effect of Biochar Application on Soil pH

All application of biochar in soil has increasing effect in soil pH. Non-significant results found in soil pH, however, has increasing effects in soil pH. Biochar pH is typically greater than 7.0 and may provide benefits when applied to acidic soils. Van Zwieten *et al.*, in 2007 reported a 30%–40% increase in wheat height when biochar was added to an acidic soil, but these effects were not evident in this study when the biochar was added to a neutral soil. CEC is an important measure of a soil's ability to retain nutrients and make them available to plants. Cheng, Lehmann, and Engelhard [8,9] showed that this benefit increases as biochar ages. Because pH increases are related to CEC increases, this benefit can be interrelated to biochar's effect on soil pH.

3.3.5. Effect of Biochar Application on Soil Organic Matter Percentage

All biochar application have some increasing effect in organic matter percentage than in the control condition and have highly significant results at 1% level of significance (Table 7). Sheep manure biochar has higher organic matter content than all other application of biochar. In addition, other biochar such as poultry manure, wood, rice husk and FYM biochar have intermediate type of effect and almost replaceable properties. Similarly organic matter increases significantly by the application of biochar.

3.3.6. Effect of Biochar Application on Soil Organic Carbon Percentage

Application of biochar have highly significant results at 1% level of significance on organic carbon percentage (Table 7). Biochar application in soil have a great role for the carbon sequestration. Here results showed that all the biochar have ability to hold carbon where the all values are more than control condition (Table 7). Among all the application sheep manure has more carbon percentage in soil than all others application. Biochar applied to soil releases carbon back into the environment at a very slow rate that is in excess of several hundreds if not thousands of years [20]. The ability of sheep manure biochar has greater holding capacity of carbon (more carbon sequestration ability) than all other biochar treatments.

Table 7. Effect of application of different origin biochar on physio-chemical properties of soil at Paklihawa, Rupandehi, Nepal, 2014/15

Treatment	Organic Matter %	Organic Carbon %	Bulk Density (gm./cc)	Particle Density (gm./cc)
Control	1.528^{c}	0.877^{c}	1.723^{a}	2.267^{d}
Rice Husk Biochar	1.883^{abc}	1.095^{abc}	1.603^{b}	2.617^{a}
Poultry Manure Biochar	2.040^{ab}	1.185^{ab}	1.602^{b}	2.370^{bcd}
Sheep Manure Biochar	2.267^{a}	1.317^{a}	1.645^{b}	2.345^{cd}
FYM Biochar	1.672^{bc}	0.972^{bc}	1.615^{b}	2.478^{b}
Wood Biochar	1.890^{abc}	1.100^{abc}	1.705^{a}	2.455^{bc}
SEm	0.121	0.071	0.016	0.035
LSD	0.366**	0.213**	0.048**	0.107**
CV %	12.880	12.900	1.390	3.040
Grand Mean	1.880	1.093	1.649	2.422

** represents the highly significant results at 1% level of significance (Note: Treatment means followed by common letter (s) are significantly different from each other based on DMRT at 5% level of significance.).

3.4. Effect of Biochar Application on Physical Properties of Soil

All application of biochar of different origin have highly significant results on bulk density and particle density at 1% level of significance (Table 7).

3.4.1. Effect of Biochar on Bulk Density

Except wood biochar, all other biochar treatment have no significant difference (Table 7). Biochar has properties to improve porosity of soil by decreasing bulk density. It has been found that all the other applications decreased the bulk density except for wood biochar. It was due to wood biochar being larger in particle size, was not thoroughly mixed to the soil in first year of application. Biochar innate porosity and very low bulk density tend to improve soil bioavailability, toxicity and mobility of organic pollutants.

3.4.2. Effect of Biochar on Particle Density

It has been found that rice husk biochar has greater particle density 2.61 g/cc than the FYM biochar having its particle density 2.47 g/cc (Table 7). Other biochar have their intermediate type of effects for soil particle density. The application of biochar have ability to slower the increment on the particle density because of lower 2.267g/cc in case of control condition (Table 7). Higher particle density represents the finer soil particle and the materials that are added to the soil thoroughly, mix, as result making the soil more porous. The more porous the soil better for the crop yield.

3.5. Pearson Correlation with Yield Attributing Parameters of Pea and Soil Physio-chemical Properties

3.5.1. Correlation of pH with Yield Attributing Parameters and Soil Chemical Properties

pH is positively correlated with different yield attributing parameters of pea and are non-significant (Table 8). Meanwhile pH is highly significant and positively correlated with potassium, organic matter and organic carbon percentage. Nitrogen percentage is significant and positively correlated with the pH however phosphorous is non-significant and positively correlated.

Table 8. Pearson correlation of pH with different yield attributing parameters of pea and soil chemical properties

	N	$P_2 0_5$	$K_2 0$	OM	CO	Pod/Plant	Seed/Pod	Biomass	GPY
pH	.469*	0.321	.541**	.518**	.519**	0.264	0.244	0.092	0.150

Values are significantly different at 5% level of significance (*) and highly significantly different at 1% level of significance (**). N = Total Nitrogen %, P_2O_5 = Available Phosphorus (Kg/ha), $K_2 0$ = Available Potassium (kg/ha), OM = Organic Matter %, CO = Organic Carbon %, Pod/Plant = No. of Pod per plant, Seed/Pod = No. of Seed per pod, Biomass = Biomass (Ton/ha), GPY = Green Pod Yield (Ton/ha).

3.5.2. Correlation of Nitrogen, Phosphorous and Potassium with Yield Attributing Parameters of Pea

Application of NPK to pea crop usually promotes vegetative growth and nodulation [37], and improves green pod yield. Vine length tended to increase as the rate of all the three nutrients increased pea, increasing phosphorus levels, generally increases green pod yield and yield components such as pod length, number of grains per pod and pod weight. Table 9 illustrate that NPK is positively correlated with all the yield attributing parameters of pea. Result have revealed that potassium is highly significant and positively correlated and phosphorous non-significant and negatively correlated to plant height after 15 DAS.

Table 9. Pearson correlation of Nitrogen with different yield attributing parameters of pea

	PHt (15 DAS)	PHt (20 DAS)	PHt (25 DAS)	PHt (30 DAS)	Pod/Plant	Seed/Pod	Biomass	GPY
N	0.275	0.277	0.320	0.368	0.153	0.325	0.061	0.209
P_20_5	-0.080	0.146	0.156	0.249	0.228	0.204	0.138	0.134
K_20	.529**	0.341	0.362	0.274	0.160	0.162	0.025	0.039

3.5.3. Correlation of Organic Matter and Organic Carbon with Yield Attributing Parameters of Pea

Organic matter has highly significant effect on the carbon content of soil. Carbon is a key ingredient in soil organic matter (57% by weight). Well-decomposed organic matter forms humus, a dark brown, porous, spongy material that provides a carbon and energy source for soil microbes and plants. Organic matter affects both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter includes soil structure, moisture holding capacity, diversity and activity of soil organisms, both those that are beneficial and harmful to crop production; and nutrient availability. It also influences the effects of chemical amendments, fertilizers, pesticides and herbicides. Result suggest that organic matter and organic carbon percentage are non-significant and positively correlated with various yield attributing character of pea.

Table 10. Pearson correlation of organic matter and organic carbon with different yield attributing parameters of pea

	PHt (15DAS)	PHt (20DAS)	PHt (25DAS)	PHt (30DAS)	Pod/Plant	Seed/Pod	Biomass	GPY
OM %	0.283	0.260	0.311	0.349	0.214	0.354	0.072	0.229
CO %	0.288	0.264	0.315	0.353	0.214	0.353	0.071	0.229

3.5.4. Pearson Correlation of Bulk Density and Particle Density with Different Yield Attributing Parameters of Pea

Bulk Density is negatively and particle density are positively correlated with the plant height, pod per plant, seed per pod, biomass and green pod yield. Bulk density have significant effect on the particle density of soil and green pod yield and highly significant effect on the pod per plant, seed per pod and biomass. USDA, soil quality kit- guide for educators, says that High bulk density is an indicator of low soil porosity and soil compaction. High bulk density impacts on available water capacity, root growth, and movement of air and water through soil. Compaction increases bulk density and reduces crop yields and vegetative cover available to protect soil from erosion. In contrast to bulk density, particle density have significant correlation with pod per plant and seed per pod.

Table 11. Pearson correlation of bulk density and particle density with different yield attributing parameters of pea

	δ_p	PHt 15DAS	PHt 20DAS	PHt 25DAS	PHt 30DAS	Pod/Plant	Seed/Pod	Biomass	GPY
δ_b	-.448*	-0.192	-0.188	-0.227	-0.162	-.825**	-.557**	-.547**	-.501*
δ_p		0.275	0.253	0.295	0.295	.501*	.449*	0.393	0.013

4. Summary and Conclusion

4.1. Summary

A field experiment was conducted at the Horticulture farm of Paklihawa Campus, Institute of Agriculture and Animal Science, Rupandehi district to observe the effect of biochar from different origin on physio-chemical properties of soil and yield of garden pea (*Pisum sativum* L.) and evaluate them. The experiment was laid out in a Randomized Complete Block Design with four replications. A set up constituted of various treatments viz. rice husk biochar, poultry manure biochar, sheep manure biochar, farm yard manure biochar and wood biochar along with the control group. Different soil parameters nitrogen %, phosphorus, potassium, pH, organic matter%, organic carbon%, bulk density (g/cc), particle density (g/cc) and plant parameters such as plant height, no. of pod and yield were recorded. Results showed that N content increased at almost same level showing significant difference in case of sheep manure biochar and poultry manure biochar followed by rice husk biochar and wood biochar. However, the values were least in case of FYM biochar and control. pH values were almost same in all treatments except control pointing the indifference in the use of any given treatment as an alternative. The results from potassium were not significantly different offering greatest value in case of rice husk biochar/sheep manure/FYM biochar/wood biochar. Values obtained from control plot (207.800) were least whereas poultry manure biochar showed intermediate results among these. Poultry manure biochar (82.527) proved best to uplift phosphorus content of soil which was accompanied by sheep manure biochar. Phosphorus level was also significantly different in rice husk biochar/FYM biochar/wood biochar and again least in control plot (38.122) proving biochar a best option for soil improvement.

Organic matter content and organic carbon content were found highest in sheep manure biochar i.e. 2.267% and 1.317% respectively and least in control condition. Following sheep manure biochar, organic carbon content was highest in poultry manure biochar. Both Rice husk biochar and wood biochar could be used as an option to organic carbon content in soil directing no significantly different result in their application. Bulk density was obtained highest in control (1.723) and wood biochar (1.705) and remaining treatment showed nearly same results with no significant difference. In the case of particle density, it was highest in rice husk biochar (2.617) followed by FYM biochar (2.478), wood biochar (2.455), poultry manure biochar (2.370), sheep manure biochar (2.345) and control (2.267) in sequence. All application of biochar of different origin have non-significant results on plant height at 15, 20, 25 and 30 DAS. Similarly, there is no substantial difference for application of different origin biochar on plant height. Conversely, the plant height is small in plot with no biochar application in contrast to plot with biochar application. Application of rice husk biochar have found more effect on pea yield attributing characters such as number of pod/plant, number of seed/pod, biomass(ton/ha) and green pod yield(ton/ha).

Talking about correlation, Total nitrogen % and available phosphorus (Kg/ha), biomass (Ton/ha) and green pod yield (Ton/ha), seed/pod and biomass, pod/plant and seed/pod and organic matter % and organic carbon % were positively correlated showing significant result at 1% level of significance. Similarly, bulk density (g/cc) and particle density (g/cc) were found to be negatively correlated and pH and Total Nitrogen % were positively correlated showing the values significantly different at 5% level of significance. Available potassium (kg/ha) and available potassium (kg/ha) were negatively correlated however the results were not significant.

According to the World Bank, approximately 1.2 billion people live on less than $1 per day and 2.7 billion people live on less than $2 per day. In short, we live in a world defined by vast economic inequality. Thus, Biochar could offer a powerful multi-pronged tactic for fighting poverty by boosting crop production, increasing on-farm income for subsistence farmers, providing the opportunity for community projects to access global market, promoting job creation through the use of local resources, reducing pressure on forest ecosystems, providing a medium for water filtration and reducing the drudgery of hauling firewood.

4.2. Conclusion

Different physical properties of the soil like bulk density and particle density and the chemical properties like N, P, K content, pH, organic carbon and organic matter content of the soil were significantly improved. The result showed the increase in the content of the considered soil parameters than the initial sample. Biochar is more stable soil amendment and it has a higher capacity to hold nutrients. Its application has shown an increased effect on the plant height, no. of pod/plant, no of seed/pod, total biomass and the overall yield of the plant. Moreover, in case of soil the significant increase in the N, P, and K, pH, organic matter, organic carbon, particle density and decrease in the bulk density has been observed from the experiment. Among different biochar, biochar of poultry and sheep manure were found to have the similar effect. Biochar not only addresses the soil reclamation but is also the measure for environment conservation. CO_2 sequestration is an important aspect of the biochar and among the biochar from different origin poultry and sheep manure biochar were found to have more effective in sequestration process. Biochar can also be suggested for the reclamation of acidic soil and can be incorporated in the sandy soil for increasing its quality. As yield of garden pea was increased using biochar, we could suggest farmers to adopt biochar application for profitable farming through sustainability. Among the biochar from different origin, application of the rice husk was found effective in increasing the particle density in comparison to other origins of biochar. Farmers in Nepal mostly practice slash/burn method, a short-term increase in nutrient availability with no any long-term effect on the soil health. This practice could be easily replaced by the formation and application of biochar. This could produce the long term beneficial effect on the soil health together with the increased yield. Also, the carbon sequestration as a measure for climate change mitigation process which is now a global burning issue could also be addressed by biochar.

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Appendix: Correlation among the selected parameters used for observation at Paklihawa, Rupandehi (2014/2015)

	N	P_20_5	K_20	OM	CO	δ_b	δ_p	PHt 15DAS	PHt 20DAS	PHt 25DAS	PHt 30DAS	Pod/Plant	Seed/Pod	Biomass	GPY
pH	.469*	0.321	.541**	.518**	.519**	-.483*	0.330	.462*	.526**	.547**	.444*	0.264	0.244	0.092	0.150
N		.516**	0.253	.977**	.978**	-0.164	-0.008	0.275	0.277	0.320	0.368	0.153	0.325	0.061	0.209
P_20_5			-0.232	.503*	.502*	-0.328	-0.052	-0.080	0.146	0.156	0.249	0.228	0.204	0.138	0.134
K_20				0.277	0.283	-0.389	0.373	.529**	0.341	0.362	0.274	0.160	0.162	0.025	0.039
OM					1.000**	-0.219	-0.002	0.283	0.260	0.311	0.349	0.214	0.354	0.072	0.229
CO						-0.221	0.003	0.288	0.264	0.315	0.353	0.214	0.353	0.071	0.229
δ_b							-.448*	-0.192	-0.188	-0.227	-0.162	-.825**	-.557**	-.547**	-.501*
δ_p								0.275	0.253	0.295	0.295	.501*	.449*	0.393	0.013
PHt 15DAS									.917**	.884**	.789**	0.053	0.159	-0.135	0.006
PHt 20DAS										.959**	.886**	0.076	0.153	-0.096	-0.018
PHt 25DAS											.947**	0.130	0.192	-0.089	-0.075
PHt 30 DAS												0.121	0.214	-0.058	-0.132
Pod/ Plant													.727**	.782**	.611**
Seed/ Pod														.850**	.557**
Biomass															.658**

Values are significantly different at 5% level of significance (*) and highly significantly different at 1% level of significance (**).

N = Total Nitrogen %, P_2O_5 = Available Phosphorus (Kg/ha), K_20 = Available Potassium (kg/Ha), OM = Organic Matter %, CO = Organic Carbon %, δ_b = Bulk Density (gm./cc), δ_p = Partical Density (gm./cc), PHt = Plant Height, DAS = Days After Sowing, Pod/Plant = No. of Pod per plant, Seed/Pod = No. of Seed per pod, Biomass = Biomass (Ton/ha), GPY = Green Pod Yield (Ton/ha).